Growth Performance, Meat Yield, and Economic Responses of Broilers Provided Diets Varying in Amino Acid Density from Thirty-Six to Fifty-Nine Days of Age[1]

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Primary Audience: Live Production Managers, Nutritionists

SUMMARY

Providing broilers diets formulated to a high amino acid density early in life improves subsequent growth performance and meat yield. Diets formulated to high amino acid concentrations beyond 5 wk of age may increase breast meat yield but may not be economically justified. This study examined growth, meat yield, and economic responses of broilers provided diets varying in amino acid density from 36 to 59 d of age. Birds were given a 4-phase feeding program: starter (1 to 17 d), grower (18 to 35 d), withdrawal-1 (WD1; 36 to 47 d), and withdrawal-2 (WD2; 48 to 59 d of age). All birds were fed a common, high amino acid density diet to 35 d of age (HH). Broilers were provided diets characterized as being high (H), moderate (M), or low (L) in amino acid density for the WD1 and WD2 periods. Dietary treatments were HHHH, HHHM, HHHL, HHMM, HHML, and HHLL from d 1 to 59, with H, M, and L representing the diets fed during each of the 4 periods (starter, grower, WD1 and WD2).

Cumulative feed conversion was improved when the HHHH feeding regimen was fed, whereas other final live performance measurements were not affected. Decreasing amino acid density (HHLL and HHHL) limited yields of breast fillets, tenders, and total white meat when compared with the HHHH regimen. As amino acid density decreased from HHHH to HHHM, HHMM, and HHML, carcass yield and breast meat yield were not affected. In general, providing the HHHH feeding regimen increased economic gross feeding margin compared with the other dietary treatments.

Key words: broiler, feeding regimen, lysine, methionine, nutrient density

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DESCRIPTION OF PROBLEM

Heavy broilers represent approximately 16% of the total broilers marketed in the United States [1]. Over the last decade, market weight of heavy broilers has been increasing and it is not uncommon for some complexes to market broilers of 3.7 kg or larger. The demand for breast fillets and value-added products has prompted primary breeding companies to develop high-yielding broilers destined to a market weight of >3.3 kg.

These newly developed broiler strains are characterized as late developing, and may have higher dietary nutrient needs as they approach

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Table 1. Ingredient and calculated nutrient composition of diets provided to male and female broilers from placement until 35 d of age[1]

Ingredient, % (as-is)	Starter − H (1 to 17 d)	Grower − H (18 to 35 d)
Ground corn	60.74	64.53
Soybean meal (48% CP)	28.36	24.93
Poultry oil	2.25	2.45
Poultry by-product meal (66% CP)	5.00	5.00
Dicalcium phosphate	1.30	1.05
Calcium carbonate	1.00	0.90
Sodium chloride	0.48	0.46
DL-Methionine	0.25	0.16
L-Lysine·HCl	0.23	0.13
Mineral and vitamin premix[2]	0.25	0.25
Copper sulfate	0.04	0.04
Zinc sulfate	0.01	0.01
Coccidostat[3]	0.08	0.08
Choline chloride	0.01	—
Total	100.00	100.00
Calculated analysis		
ME, kcal/kg	3,085	3,140
CP, %	22.5	21.0
TSAA, %	0.98	0.88
Lysine, %	1.36	1.18

[1]Diet characterized as being formulated to high (H) amino acid density specifications. Calculated calcium, available phosphorus, and choline were 0.94%, 0.47%, and 1,700 ppm and 0.84%, 0.42%, and 1,600 ppm in the starter and grower diets, respectively. Actual CP concentrations were 22.0 and 20.6%, respectively, in the starter and grower diets.

[2]Vitamin and mineral premix include per kilogram of diet: vitamin A (vitamin A acetate) 7,716 IU; cholecalciferol 2,205 IU; vitamin E (source unspecified) 9.9 mg; menadione, 0.9 mg; B_{12}, 0.01 mg; folic acid, 0.6 μg: choline, 379 mg; D-pantothenic acid, 8.8 mg; riboflavin, 5.0 mg; niacin, 33 mg; thiamin, 1.0 mg; D-biotin, 0.06 mg; pyridoxine, 0.9 mg; ethoxyquin, 28 mg; manganese, 55 mg; zinc, 50 mg; iron, 28 mg; copper, 4 mg; iodine, 0.5 mg; selenium, 0.1 mg.

[3]Coban 60, Elanco Products, Inc., Indianapolis, IN.

market weight than multipurpose strains. As a result, primary breeding companies advocate high nutrient density diets in their production guides for these newly developed strains [2], but recommendations are only provided for a maximum bird weight of 3.0 kg. Because approximately 70% of the total feed usage occurs after 5 wk of age with broilers marketed at 3.7 to 4.0 kg, broiler integrators tend to feed diets formulated to lower amino acid specifications as a means to reduce live production cost. When assessing profitability, feed cost should be expressed per unit of meat produced and not solely on live production cost. Defining amino acid needs is economically important late in production to ensure that amino acids are not fed in excess, but not meeting dietary amino acid needs can impair meat yield.

Providing diets formulated to high amino acid density has been shown to optimize subsequent growth and meat yield responses [3, 4, 5, 6]. Formulating diets containing a relatively high amount of CP and amino acids to the young chick enhances nitrogen reserves for subsequent development [7]. The response to increasing dietary amino acid density early in development may relate to an increase in insulin-like growth factor-I concentrations [8, 9], which in turn, increases protein synthesis [10] leading to larger muscle fiber diameter [11]. Skinner et al. [12] reported that decreasing dietary amino acid density from 100 to 70% of amino acid recommendations [13] from d 44 to 49 did not influence growth rate, feed conversion, or carcass yield. However, Skinner et al. [12] used a lower yielding broiler compared with genetic strains currently available.

Modern broiler strains selected for breast meat yield respond to diets formulated to a high amino acid density throughout production [6, 14, 15]. Breast meat may be increased by 1.5 to 2.0 percentage points when feeding high amino acid density diets throughout grow-out. However, carryover effects of dietary amino acid density may occur from the starter and grower periods to the withdrawal (**WD**) periods. Therefore, feeding high amino acid density diets from 5 to 8 wk may not be warranted. Information is lacking on feeding the Ross × Ross 708 [16] broiler high amino acid density diets early in life and decreasing dietary amino acid density beyond 5 wk of age on growth performance and meat yield. This study examined growth performance, meat yield, and economics of Ross × Ross 708 broilers provided 6 dietary treatments from 36 to 59 d.

MATERIALS AND METHODS

Bird Husbandry

Two identical trials were conducted. In each trial, 1,560 1-d-old Ross × Ross 708 [16] broiler chicks were purchased from a commercial hatchery and randomly distributed into 30 floor pens (26 males and 26 females; 0.07 m²/bird) of a

Table 2. Ingredient and calculated nutrient composition of diets provided to male and female broilers from 36 to 59 d of age

Ingredient, %	WD1 (36 to 47 d)			WD2 (48 to 59 d)		
	H[1]	M[2]	L[3]	H	M	L
Ground corn	66.86	71.96	76.71	72.16	74.25	78.36
Soybean meal (48% CP)	22.22	17.99	14.08	17.40	15.72	12.35
Poultry oil	3.35	2.40	1.53	2.73	2.36	1.61
Poultry by-product meal (66% CP)	5.00	5.00	5.00	5.00	5.00	5.00
Dicalcium phosphate	0.81	0.83	0.86	0.84	0.85	0.87
Calcium carbonate	0.80	0.81	0.81	0.81	0.81	0.82
Sodium chloride	0.46	0.46	0.46	0.46	0.46	0.46
DL-Methionine	0.14	0.15	0.14	0.14	0.13	0.11
L-Lysine·HCl	0.06	0.08	0.09	0.16	0.11	0.11
Mineral and vitamin premix[4]	0.25	0.25	0.25	0.25	0.25	0.25
Copper sulfate	0.05	0.05	0.05	0.05	0.05	0.05
Zinc sulfate	0.01	0.01	0.01	0.01	0.01	0.01
Total	100.00	100.00	100.00	100.00	100.00	100.00
Calculated analysis						
ME, kcal/kg	3,220	3,220	3,220	3,240	3,240	3,240
CP, %	19.8	18.2	16.7	18.0	17.3	16.0
TSAA, %	0.83	0.80	0.75	0.78	0.75	0.70
Lysine, %	1.05	0.95	0.85	1.00	0.91	0.82
Digestible lysine, %	0.93	0.84	0.75	0.89	0.80	0.72
Digestible TSAA, %	0.73	0.70	0.66	0.69	0.65	0.61
Digestible threonine, %	0.64	0.58	0.53	0.58	0.55	0.51
Digestible valine, %	0.80	0.73	0.67	0.72	0.69	0.64
Digestible isoleucine, %	0.71	0.64	0.57	0.63	0.60	0.54

[1]Diet characterized as being formulated to high (H) amino acid density concentrations. Calculated calcium, available phosphorus, and choline were 0.74%, 0.37%, and 1,400 ppm. Actual CP concentrations were 19.5 and 17.3%, respectively, in the withdrawal (WD1 and WD2) diets.
[2]Diet characterized as being formulated to moderate (M) amino acid density concentrations. Calculated calcium, available phosphorus, and choline were 0.74%, 0.37%, and 1,400 ppm. Actual CP concentrations were 18.2 and 16.6%, respectively, in the WD1 and WD2 diets.
[3]Diet characterized as being formulated to low (L) amino acid density concentrations. Calculated calcium, available phosphorus, and choline were 0.74%, 0.37%, and 1,400 ppm. Actual CP concentrations were 16.3 and 15.8%, respectively, in the WD1 and WD2 diets.
[4]Vitamin and mineral premix include per kilogram of diet: vitamin A (vitamin A acetate) 7,716 IU; cholecalciferol 2,205 IU; vitamin E (source unspecified) 9.9 mg; menadione, 0.9 mg; B_{12}, 0.01 mg; folic acid, 0.6 μg; choline, 379 mg; D-pantothenic acid, 8.8 mg; riboflavin, 5.0 mg; niacin, 33 mg; thiamin, 1.0 mg; D-biotin, 0.06 mg; pyridoxine, 0.9 mg; ethoxyquin, 28 mg; manganese, 55 mg; zinc, 50 mg; iron, 28 mg; copper, 4 mg; iodine, 0.5 mg; selenium, 0.1 mg.

solid-sided facility. Chicks from both trials originated from eggs produced by the same breeder flock only 2 wk apart. Vaccinations for Marek's disease, Newcastle disease, and infectious bronchitis were administered at the hatchery, and vaccination against infectious bursal disease virus was given at 12 d of age. Each pen was equipped with 1 pan feeder, a nipple waterer line having 9 nipples (flow rate = 35 mL/min for 1 to 35 d; 70 mL/min for 36 to 59 d of age), and fresh pine shavings. A feeder lid was placed in each pen from 1 to 7 d to ensure chicks had adequate access to feed. Feed and water were available to the birds for ad libitum consumption. Temperature was maintained at 33°C at

placement and reduced as the birds progressed in age with a final temperature of 14°C at 56 d [17]. The lighting schedule used was intended not to restrict early growth [18].

Dietary Treatments

Common diets were provided from 1 to 35 d of age (Table 1). At 36 d of age, 6 feeding treatments were fed until 59 d of age. Birds were given a 4-phase feeding regimen consisting of starter (1 to 17 d), grower (18 to 35 d), WD1 (36 to 47 d), and WD2 (48 to 59 d). The diets in the starter and grower periods were high (**H**) amino acid density and those in WD1 and WD2

Table 3. Live performance responses of male and female broilers provided varying in dietary amino acid density (high, moderate, and low; H, M, and L) from placement to 47 d of age (WD1)[1]

Dietary treatments	BW (g)	BW gain (g)	FC[2] (g)	FG[3]	Mortality (%)
HHH[4]	3,123[a]	3,077[a]	5,391[b]	1.751[b]	2.5
HHM[5]	3,139[a]	3,093[a]	5,454[ab]	1.766[b]	2.5
HHL[6]	3,074[b]	3,028[b]	5,495[a]	1.815[a]	3.0
SEM	18	18	38	0.007	0.8
Least significant difference (critical value)	47	47	103	0.019	2.1
			Probabilities		
Planned contrasts					
HHL vs. HHM	0.0025	0.003	0.421	0.0001	0.602
HHH vs. HHM	0.307	0.311	0.064	0.055	0.999

[a,b]Mean values within a column with no common letters are significantly different ($P < 0.05$) as a result of a least significance difference comparison.

[1]Values represent least squares means of 10 replicate pens with each having 52 chicks (26 males and 26 females) at placement. Average chick weight at placement was 46 g.

[2]FC = Feed consumption per bird.

[3]FG = Feed conversion corrected for mortality.

[4]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, and 19.8% CP, 0.83% TSAA, and 1.05% lysine, in the starter, grower, and withdrawal (WD1) periods, respectively.

[5]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, and 18.2% CP, 0.80% TSAA, and 0.95% lysine, in the starter, grower, and WD1 periods, respectively.

[6]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, and 16.7% CP, 0.75% TSAA, and 0.85% lysine, in the starter, grower, and WD1 periods, respectively.

were formulated to H, moderate (**M**), and low (**L**) amino acid densities that would be used in commercial practice [6] (Table 2). The 6 feeding treatments throughout the 59-d production period were: HHLL, HHML, HHMM, HHHH, HHHM, and HHHL. The HHML treatment, for example, was H amino acid density for starter and grower periods (HH), M amino acid density for WD1, and L amino acid density for WD2.

The NRC [19] recommends 1.0% dietary lysine from 21 to 42 d and 0.85% dietary lysine during 42 to 56 d. Regimen HHHH exceeded NRC lysine recommendations from 21 to 42 and 42 to 56 d. Regimen HHMM was below the 21- to 42-d NRC lysine recommendation during the 21- to 42-d period, but exceeded the NRC lysine recommendation from 42 to 56 d. Regimen HHLL was below NRC lysine recommendations from 21 to 42 and 42 to 56 d. Regimens HHHM, HHHL, and HHML were intermediate in lysine content when compared with regimens HHHH, HHMM, and HHLL. All regimens exceeded NRC recommendations for TSAA during 21 to 56 d of age.

Measurements

Birds and feed were weighed by pen at 1, 17, 35, 47, and 59 d of age. Feed consumption

was divided by BW on a bird basis to calculate feed conversion ratio. The incidence of mortality was recorded daily. At 60 d of age, 12 birds per pen (6 males and 6 females) were randomly selected for processing and placed in transportation coops. Feed was removed from each pen 12 h before processing. Birds were electrically stunned, bled with a knife by severing the jugular vein, scalded, defeathered, and manually eviscerated. Carcasses and abdominal fat were weighed and carcasses were chilled in ice for 24 h. Front halves were deboned. Boneless, skinless breast fillets and tenders (pectoralis major and pectoralis minor muscles) were weighed. Carcass, breast fillets, breast tenders, abdominal fat, and total white meat (breast fillets + breast tenders) yields were calculated relative to final BW.

Economics

Sensitivity analysis was performed to determine gross feeding margin on a carcass and total white meat basis. The sensitivity analysis includes a wide range of diet cost and meat prices that allow the determination of an optimum dietary treatment of a given scenario based on diet cost and meat prices. Twenty-four scenarios were developed to estimate gross feeding margin per bird based on diet cost and meat

Table 4. Live performance responses of male and female broilers provided varying in dietary amino acid density (high, moderate, and low; H, M, and L) from placement to 59 d of age (WD2)[1]

Dietary treatments	BW (g)	BW gain (g)	FC[2] (g)	FG[3]	Mortality (%)
HHHH[4]	3,953	3,908	7,520	1.923[c]	3.8
HHHM[5]	3,955	3,909	7,615	1.947[b]	2.7
HHHL[6]	3,884	3,838	7,529	1.963[b]	3.9
HHMM[7]	3,957	3,911	7,616	1.948[b]	3.5
HHML[8]	3,919	3,873	7,579	1.958[b]	3.3
HHLL[9]	3,900	3,855	7,667	1.990[a]	4.1
SEM	30	30	56	0.008	0.9
Least significant difference (critical value)	83	83	156	0.022	9.5
			Probabilities		
Planned contrasts					
HHHH, HHHM, HHHL, HHMM, HHML vs. HHLL	0.322	0.323	0.132	0.0001	0.508
HHHH, HHHM, HHHL, HHMM vs. HHML, HHLL	0.825	0.821	0.146	0.001	0.830
HHML vs. HHMM	0.347	0.343	0.619	0.349	0.900
HHMM vs. HHHH	0.940	0.940	0.218	0.026	0.797
HHHH vs. HHHM	0.990	0.986	0.225	0.032	0.394

[a–c]Mean values within a column with no common letters are significantly different ($P < 0.05$) as a result of a least significance difference comparison.

[1]Values represent least squares means of 10 replicate pens with each having 52 chicks (26 males and 26 females) at placement. Average chick weight at placement was 46 g.

[2]FC = Feed consumption per bird.

[3]FG = Feed conversion corrected for mortality.

[4]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 19.8% CP, 0.83% TSAA, and 1.05% lysine, and 18.0% CP, 0.78% TSAA, and 1.00% lysine in the starter, grower, WD1, and WD2 periods, respectively.

[5]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 19.8% CP, 0.83% TSAA, and 1.05% lysine, and 17.3% CP, 0.75% TSAA, and 0.91% lysine in the starter, grower, WD1, and WD2 periods, respectively.

[6]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 19.8% CP, 0.83% TSAA, and 1.05% lysine, and 16.0% CP, 0.70% TSAA, and 0.82% lysine in the starter, grower, WD1, and WD2 periods, respectively.

[7]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 18.2% CP, 0.80% TSAA, and 0.95% lysine, 17.3% CP, 0.75% TSAA, and 0.91% lysine in the starter, grower, WD1, and WD2 periods, respectively.

[8]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 18.2% CP, 0.80% TSAA, and 0.95% lysine, and 16.0% CP, 0.70% TSAA, and 0.82% lysine in the starter, grower, WD1, and WD2 periods, respectively.

[9]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 16.7% CP, 0.75% TSAA, and 0.85% lysine, and 16.0% CP, 0.70% TSAA, and 0.82% lysine in the starter, grower, WD1, and WD2 periods, respectively.

prices. Base diet cost was estimated on southeastern United States ingredient prices as of March 2005. Diet cost among the treatments for the ingredient prices as of March 2005 was considered the base price (100%) and was decreased to 80% of the base price and increased to 120% of the base price to reflect market fluctuations occurring during a 12-mo period. Base meat prices were $1.32/kg, $3.32/kg, and $3.97/kg to represent carcass, breast fillet, and breast tender prices, respectively. Meat prices varied from 70 to 130% of base prices for carcass, breast fillets, and breast tenders. Gross feeding margin per bird was calculated as output (meat price × meat weight) minus input (feed cost = diet cost × feed consumption) [20].

Statistics

Data were statistically evaluated by the GLM [21] in a randomized complete block design. Pen was considered the experimental unit. Each treatment was represented by 10 replicate pens (5 replicate pens/trial). Five orthogonal contrasts were used to separate treatment means. In addition, least significant difference comparison was used to separate treatment means. Statistical significance was considered at $P \leq 0.05$.

Table 5. Carcass yield of male and female broilers provided varying in dietary amino acid density (high, moderate, and low; H, M, and L) from placement to 59 d of age[1]

Dietary treatments	BW (g)	Carcass		Abdominal fat	
		Weight[2] (g)	Yield[3] (%)	Weight (g)	Yield[3] (%)
HHHH[4]	3,867	2,653	68.6	92[b]	2.37[b]
HHHM[5]	3,876	2,668	68.8	92[b]	2.36[b]
HHHL[6]	3,842	2,631	68.5	97[ab]	2.50[ab]
HHMM[7]	3,887	2,665	68.6	98[ab]	2.52[ab]
HHML[8]	3,869	2,645	68.4	101[a]	2.63[a]
HHLL[9]	3,884	2,654	68.4	102[a]	2.63[a]
SEM	32	26	0.3	3	0.06
Least significant difference (critical value)	88	71	0.8	7	0.17
		Probabilities			
Planned contrasts					
HHHH, HHHM, HHHL, HHMM, HHML vs. HHLL	0.659	0.941	0.500	0.016	0.023
HHHH, HHHM, HHHL, HHMM vs. HHML, HHLL	0.483	0.822	0.399	0.0009	0.0009
HHML vs. HHMM	0.668	0.568	0.628	0.364	0.357
HHMM vs. HHHH	0.665	0.726	0.985	0.099	0.076
HHHH vs. HHHM	0.853	0.672	0.527	0.972	0.960

[a,b]Mean values within a column with no common letters are significantly different ($P < 0.05$) as a result of a least significance difference comparison.
[1]Values represent least squares means of 10 replicate pens with each representing 12 carcasses (6 males and 6 females).
[2]Carcasses without necks and giblets after 24 h static chilling.
[3]Yield is relative to BW.
[4]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 19.8% CP, 0.83% TSAA, and 1.05% lysine, and 18.0% CP, 0.78% TSAA, and 1.00% lysine in the starter, grower, WD1, and WD2 periods, respectively.
[5]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 19.8% CP, 0.83% TSAA, and 1.05% lysine, and 17.3% CP, 0.75% TSAA, and 0.91% lysine in the starter, grower, WD1, and WD2 periods, respectively.
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[7]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 18.2% CP, 0.80% TSAA, and 0.95% lysine, 17.3% CP, 0.75% TSAA, and 0.91% lysine in the starter, grower, WD1, and WD2 periods, respectively.
[8]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 18.2% CP, 0.80% TSAA, and 0.95% lysine, and 16.0% CP, 0.70% TSAA, and 0.82% lysine in the starter, grower, WD1, and WD2 periods, respectively.
[9]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 16.7% CP, 0.75% TSAA, and 0.85% lysine, and 16.0% CP, 0.70% TSAA, and 0.82% lysine in the starter, grower, WD1, and WD2 periods, respectively.

RESULTS AND DISCUSSION

Analysis of the experimental diets determined that the actual composition of CP was lower than the calculated values (Tables 1 and 2). Data were pooled from the 2 trials because trial × treatment interactions were not different ($P \geq 0.80$) for the variables measured. The 2 trials were conducted from January to March 2005 and ambient temperature in the experimental facility was favorable throughout the 59-d production period [22]. The grand means for BW and feed conversion were 550 g and 1.31 (1 to 17 d) and 2,004 g and 1.58 (1 to 35 d),

respectively, indicating that the birds had favorable growth and feed conversion before initiation of the experimental periods.

Decreasing dietary amino acid density during 36 to 47 d (WD1) from HHH to HHM did not alter growth performance (Table 3). However, reducing dietary amino acid density from HHH and HHM to HHL limited growth rate and adversely affected feed conversion. Dietary amino acid density did not influence the incidence of mortality. Feeding the HHHH regimen through WD2 improved cumulative feed conversion over birds provided HHHM, HHHL, HHMM, HHML, and HHLL regimens (Table 4). Dietary

Table 6. Boneless, skinless, breast meat yield of male and female broilers provided varying in dietary amino acid density (high, moderate, and low; H, M, and L) from placement to 59 d of age[1]

Dietary treatments	Pectoralis major		Pectoralis minor		Total breast	
	Weight (g)	Yield[2] (%)	Weight (g)	Yield[2] (%)	Weight (g)	Yield[2] (%)
HHHH[3]	680	17.6[a]	144[a]	3.72[b]	824	21.3[a]
HHHM[4]	681	17.6[a]	142[ab]	3.67[ab]	823	21.2[ab]
HHHL[5]	665	17.3[ab]	140[ab]	3.65[ab]	805	20.9[bc]
HHMM[6]	676	17.4[ab]	143[ab]	3.68[ab]	820	21.0[ab]
HHML[7]	672	17.4[ab]	140[ab]	3.62[ab]	812	21.0[ab]
HHLL[8]	663	17.1[b]	139[b]	3.57[a]	802	20.6[c]
SEM	9	0.1	2	0.04	10	0.1
Least significant difference (critical value)	24	0.4	5	0.12	26	0.4
			Probabilities			
Planned contrasts						
HHHH, HHHM, HHHL, HHMM, HHML vs. HHLL	0.214	0.014	0.133	0.042	0.156	0.002
HHHH, HHHM, HHHL, HHMM vs. HHML, HHLL	0.499	0.057	0.333	0.109	0.419	0.017
HHML vs. HHMM	0.690	0.824	0.255	0.276	0.547	0.549
HHMM vs. HHHH	0.792	0.338	0.741	0.487	0.751	0.237
HHHH vs. HHHM	0.903	0.981	0.484	0.330	0.965	0.725

[a–c]Mean values within a column with no common letters are significantly different ($P < 0.05$) as a result of a least significance difference comparison.
[1]Values represent least squares means of 10 replicate pens with each representing 12 carcasses (6 males and 6 females).
[2]Yield is relative to BW.
[3]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 19.8% CP, 0.83% TSAA, and 1.05% lysine, and 18.0% CP, 0.78% TSAA, and 1.00% lysine in the starter, grower, WD1, and WD2 periods, respectively.
[4]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 19.8% CP, 0.83% TSAA, and 1.05% lysine, and 17.3% CP, 0.75% TSAA, and 0.91% lysine in the starter, grower, WD1, and WD2 periods, respectively.
[5]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 19.8% CP, 0.83% TSAA, and 1.05% lysine, and 16.0% CP, 0.70% TSAA, and 0.82% lysine in the starter, grower, WD1, and WD2 periods, respectively.
[6]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 18.2% CP, 0.80% TSAA, and 0.95% lysine, 17.3% CP, 0.75% TSAA, and 0.91% lysine in the starter, grower, WD1, and WD2 periods, respectively.
[7]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 18.2% CP, 0.80% TSAA, and 0.95% lysine, and 16.0% CP, 0.70% TSAA, and 0.82% lysine in the starter, grower, WD1, and WD2 periods, respectively.
[8]Diets were formulated to contain 22.5% CP, 0.98% TSAA, and 1.36% lysine, 21.0% CP, 0.88% TSAA, and 1.18% lysine, 16.7% CP, 0.75% TSAA, and 0.85% lysine, and 16.0% CP, 0.70% TSAA, and 0.82% lysine in the starter, grower, WD1, and WD2 periods, respectively.

treatments did not affect 59-d BW, BW gain, feed consumption, or the occurrence of mortality.

In the current study, cumulative feed conversion was increased by 2, 3, 4, 4, and 7 points, respectively, as dietary amino acid density was decreased from HH to HM, HH to MM, HH to HL, HH to ML, and HH to LL from 36 to 59 d of age, but BW gain was unaffected. In agreement, previous research also found no differences in BW gain from 6 to 8 wk of age in broilers provided diets formulated to moderate or high nutrient density [14, 15]. However, feeding an H amino acid density diet to Ross × Ross 708

[16] did improve feed conversion by 4 points from 45 to 55 d of age compared with birds fed feeds formulated to an M amino acid density [15]. The BW gain response to amino acid density appears to be more acute from 5 to 7 wk of age than from 6 to 8 wk. Kidd et al. [6] fed diets varying in amino acid density to Ross × Ross 508 broilers [16] during a 49-d production period. Growth rate for broilers consuming diets formulated to an amino acid density of H, M, and L from 36 to 49 d of age was 1,000, 879, and 822 g, respectively.

Feeding diets differing in amino acid density from 36 to 59 d of age did not alter the weight or

Table 7. Sensitivity analysis ($/bird) based upon total feed cost and meat yield of male and female broilers provided diets varying in amino acid density from 36 to 59 d of age

Total feed cost[3,4,5,6,7,8] (% of base)	Meat prices (% of base)[1,2]												
	70		80		90		100		110		120		130	
	White meat	Carcass	White meat	Carcass	White meat	Carcass	White meat	Carcass	White meat	Carcass	White meat	Carcass	White meat	Carcass
HHHH														
80	1.032	1.507	1.315	1.857	1.597	2.207	1.879	2.557	2.162	2.907	2.444	3.258	2.727	3.608
90	0.914	1.389	1.197	1.739	1.479	2.089	1.761	2.439	2.044	2.789	2.326	3.140	2.609	3.490
100	0.796	1.271	1.079	1.621	1.361	1.971	1.643	2.321	1.926	2.671	2.208	3.022	2.491	3.372
110	0.678	1.153	0.961	1.503	1.243	1.853	1.525	2.203	1.808	2.553	2.090	2.903	2.372	3.254
120	0.560	1.035	0.843	1.385	1.125	1.735	1.407	2.085	1.690	2.435	1.972	2.785	2.254	3.136
HHHM														
80	1.020	1.508	1.303	1.860	1.585	2.212	1.867	2.564	2.149	2.916	2.432	3.268	2.714	3.620
90	0.901	1.389	1.183	1.741	1.465	2.093	1.748	2.445	2.030	2.797	2.312	3.149	2.595	3.501
100	0.781	1.270	1.064	1.622	1.346	1.974	1.628	2.326	1.911	2.678	2.193	3.030	2.475	3.382
110	0.662	1.150	0.944	1.502	1.227	1.854	1.509	2.206	1.791	2.558	2.073	2.910	2.356	3.262
120	0.543	1.031	0.825	1.383	1.107	1.735	1.389	2.087	1.672	2.439	1.954	2.791	2.236	3.143
HHHL														
80	1.001	1.503	1.277	1.851	1.553	2.198	1.828	2.545	2.104	2.893	2.380	3.240	2.655	3.588
90	0.885	1.387	1.161	1.735	1.437	2.082	1.712	2.429	1.988	2.777	2.264	3.124	2.539	3.472
100	0.769	1.271	1.045	1.619	1.320	1.966	1.596	2.313	1.872	2.661	2.147	3.008	2.423	3.355
110	0.653	1.155	0.929	1.502	1.204	1.850	1.480	2.197	1.756	2.545	2.031	2.892	2.307	3.239
120	0.537	1.039	0.813	1.386	1.088	1.734	1.364	2.081	1.640	2.429	1.915	2.776	2.191	3.123
HHMM														
80	1.028	1.527	1.308	1.879	1.589	2.231	1.870	2.583	2.150	2.935	2.431	3.287	2.712	3.639
90	0.911	1.410	1.191	1.762	1.472	2.114	1.753	2.466	2.033	2.818	2.314	3.170	2.595	3.522
100	0.794	1.293	1.074	1.645	1.355	1.997	1.636	2.349	1.916	2.701	2.197	3.053	2.477	3.405
110	0.676	1.176	0.957	1.528	1.238	1.880	1.518	2.232	1.799	2.584	2.080	2.936	2.360	3.288
120	0.559	1.059	0.840	1.411	1.121	1.763	1.401	2.115	1.682	2.466	1.963	2.818	2.243	3.170

Continued

Table 7 (Continued).

Total feed cost[3,4,5,6,7,8] (% of base)	Meat prices (% of base)[1,2]												
	70		80		90		100		110		120		130	
	White meat	Carcass	White meat	Carcass	White meat	Carcass	White meat	Carcass	White meat	Carcass	White meat	Carcass	White meat	Carcass
HHML														
80	1.027	1.523	1.305	1.872	1.584	2.222	1.862	2.571	2.141	2.920	2.419	3.270	2.697	3.619
90	0.912	1.408	1.190	1.757	1.468	2.106	1.747	2.456	2.025	2.805	2.304	3.154	2.582	3.504
100	0.796	1.292	1.075	1.642	1.353	1.991	1.632	2.340	1.910	2.690	2.188	3.039	2.467	3.388
110	0.681	1.177	0.959	1.526	1.238	1.876	1.516	2.225	1.795	2.574	2.073	2.924	2.352	3.273
120	0.566	1.062	0.844	1.411	1.123	1.761	1.401	2.110	1.679	2.459	1.958	2.809	2.236	3.158
HHLL														
80	1.005	1.536	1.280	1.886	1.555	2.237	1.830	2.588	2.105	2.938	2.379	3.289	2.654	3.640
90	0.890	1.421	1.165	1.771	1.440	2.122	1.715	2.473	1.990	2.823	2.265	3.174	2.539	3.525
100	0.775	1.306	1.050	1.656	1.325	2.007	1.600	2.358	1.875	2.708	2.150	3.059	2.425	3.410
110	0.660	1.191	0.935	1.542	1.210	1.892	1.485	2.243	1.760	2.594	2.035	2.944	2.310	3.295
120	0.545	1.076	0.820	1.427	1.095	1.777	1.370	2.128	1.645	2.479	1.920	2.829	2.195	3.180

[1]Base pectoralis major price is $3.31/kg and pectoralis minor $3.97/kg.

[2]Base carcass price is $1.32/kg.

[3]Base total feed cost for the regimen HHHH is $1.180 and is derived by multiplying feed consumption for each growth period by diet cost. For this feeding regimen, diet costs were as follows: starter period, $0.175/kg; grower period, $0.164/kg; WD1 period, $0.153/kg; WD2 period, $0.148/kg.

[4]Base total feed cost for the regimen HHHM is $1.187 and is derived by multiplying feed consumption for each growth period by diet cost. For this feeding regimen, diet costs were as follows: starter period, $0.175/kg; grower period, $0.164/kg; WD1 period, $0.153/kg; WD2 period, $0.144/kg.

[5]Base total feed cost for the regimen HHHL is $1.161 and is derived by multiplying feed consumption for each growth period by diet cost. For this feeding regimen, diet costs were as follows: starter period, $0.175/kg; grower period, $0.164/kg; WD1 period, $0.153/kg; WD2 period, $0.138/kg.

[6]Base total feed cost for the regimen HHMM is $1.171 and is derived by multiplying feed consumption for each growth period by diet cost. For this feeding regimen, diet costs were as follows: starter period, $0.175/kg; grower period, $0.164/kg; WD1 period, $0.146/kg; WD2 period, $0.144/kg.

[7]Base total feed cost for the regimen HHML is $1.153 and is derived by multiplying feed consumption for each growth period by diet cost. For this feeding regimen, diet costs were as follows: starter period, $0.175/kg; grower period, $0.164/kg; WD1 period, $0.146/kg; WD2 period, $0.138/kg.

[8]Base total feed cost for the regimen HHLL is $1.149 and is derived by multiplying feed consumption for each growth period by diet cost. For this feeding regimen, diet costs were as follows: starter period, $0.175/kg; grower period, $0.164/kg; WD1 period, $0.140/kg; WD2 period, $0.138/kg.

yield of the whole carcass (Table 5). Decreasing amino acid density from HHHH and HHHM to HHML and HHLL increased the absolute and relative yield of abdominal fat. In contrast, Kidd et al. [15] reported no differences in abdominal fat in broilers fed HH or MM diets from 36 to 55 d. Other research found less abdominal fat with increasing amino acid density from 1 to 56 d of age [14].

Broilers provided HHHH diets had greater breast fillet and total breast meat yield compared with birds fed the HHLL regimen (Table 6). However, broilers given the HHHM, HHMM, and HHML regimens produced similar total breast meat yield compared with birds provided the HHHH feeding program. In agreement, decreasing dietary amino acid density from HH to MM or ML from 36 to 55 d did not affect breast meat yield [15]. The lysine content in the M diets from 36 to 45 and 46 to 55 d reported by Kidd et al. [15] was similar to H diets fed from 36 to 47 and 48 to 59 d in the current study. Thus, the M diets provided from 36 to 55 d in the study by Kidd et al. [15] may have met the dietary amino acid needs of the bird and the amino acids supplied by the H diets could have been too high. Corzo et al. [14] found a 2.6% proportional increase in breast meat yield (19.8 vs. 19.3%) with increasing dietary amino acid density from 1 to 56 d. However, the 2.5% increase in breast meat yield may have occurred due to carryover effects of increasing amino acid density during the first few weeks of the grow out.

Sensitivity analysis of gross feeding margin per bird indicated that changing meat and feed prices affected the economic value of differences in response to the dietary treatments (Table 7). At base levels of diet cost and breast meat prices, feeding the HHHH diets increased gross feeding margin by \$0.015, \$0.047, \$0.007, \$0.011, and \$0.043/bird, respectively, compared with the HHHM, HHHL, HHMM, HHML, and HHLL regimens. These differences increase as breast meat price increases. For example, with breast meat prices at 130% of the base price, feeding the HHHH regimen increased gross feeding margin by \$0.016, \$0.068, \$0.014, \$0.024, and \$0.066/bird compared with the HHHM, HHHL, HHMM, HHML, and HHLL feeding programs, respectively (with diet cost remaining at 100% of the base price). Conversely, decreasing breast meat prices reduced the economic differences between treatments. By decreasing breast meat prices to 80% of the base price, the return of gross feeding margins was increased by \$0.015, \$0.034, \$0.005, \$0.004, and \$0.029/bird when the HHHH program was given over the HHHM, HHHL, HHMM, HHML, and HHLL regimens, respectively (again, with diet cost at 100% of the base price). Feeding the HHHH regimen with diet cost and breast meat prices at 100% of the base cost would generate an additional \$7,000 and \$11,000/wk for a complex processing 1 million broilers compared with the HHMM and HHML feeding programs, respectively.

Evaluating the dietary treatments using breast meat prices at 100% and increasing diet cost to 120% revealed that feeding the HHHH regimen increased profits by \$0.018, \$0.043, \$0.006, \$0.006, \$0.037/bird, respectively, compared with the HHHM, HHHL, HHMM, HHML, and HHLL feeding regimens. When diet cost was 80% and breast meat prices were at 100% of the base prices, broilers fed the HHHH had an increase of gross feeding margin per bird of \$0.012, \$0.051, \$0.009, \$0.017, and \$0.049, respectively, compared with broilers given the HHHM, HHHL, HHMM, HHML, and HHLL feeding treatments. As diet cost increased to 120% of the base price with breast prices held at 100% of base price, decreasing amino acid density from HHHH to HHMM only reduced gross feeding margin by \$0.006/bird.

CONCLUSIONS AND APPLICATIONS

1. Increasing dietary amino acid density from 36 to 59 d improved cumulative feed conversion, but did not alter final growth rate, feed consumption, and the incidence of mortality.
2. Feeding the HHHH regimen increased breast fillet yield, breast tender yield, and total breast meat yield compared with broilers provided the HHLL regimen. Decreasing dietary amino acid density to HHHM, HHMM, and HHML did not significantly affect the yield of saleable white meat.

3. In general, broilers given the HHHH regimen had greater gross feeding margin than the other dietary treatments. However, as breast meat prices increased, the difference of gross feeding margin was more pronounced when feeding H amino acid density diets from 36 to 59 d of age.

4. Consideration to breast meat prices and diet cost should be given collectively when establishing commercial feeding programs for broilers grown to heavy market weights.

REFERENCES AND NOTES

1. Brister, R. 2004. United States broiler nutritional strategies. Arkansas Nutrition Conference, Springdale, AR.

2. Ross × Ross 708 North American Broiler Performance Objectives. Aviagen North America, Huntsville, AL.

3. Holsheimer, J. P., and E. W. Ruesink. 1993. Effect on performance, carcass composition, yield, and financial return of dietary energy and lysine levels in starter and finisher diets fed to broilers. Poult. Sci. 72:806–815.

4. Kidd, M. T., B. J. Kerr, K. M. Halpin, G. W. McWard, and C. L. Quarles. 1998. Lysine interactions in broilers in starter and grower-finisher diets. J. Appl. Poult. Res. 7:351–358.

5. Bartov, I., and I. Plavnik. 1998. Moderate excess of dietary protein increases breast meat yield of broiler chicks. Poult. Sci. 77:680–688.

6. Kidd, M. T., C. D. McDaniel, S. L. Branton, E. R. Miller, B. B. Boren, and B. I. Fancher. 2004. Increasing amino acid density improves live performance and carcass yields of commercial broilers. J. Appl. Poult. Res. 13:593–604.

7. Fisher, H., J. Grun, R. Shapiro, and J. Ashley. 1964. Protein reserves: Evidence for their utilization under nutritional and disease stress conditions. J. Nutr. 83:165–170.

8. Rosebrough, R. W., A. D. Mitchell, and P. J. McMurty. 1996. Dietary crude protein changes rapidly after metabolism and plasma insulin-like growth factor I concentrations in broiler chickens. J. Nutr. 126:2888–2898.

9. Tesseraud, S., R. A. Pym, E. Le Bihan-Duval, and M. J. Duclos. 2003. Response of broilers selected on carcass quality to dietary protein supply: Live performance, muscle development, and circulating insulin-like growth factors (IGF-I and -II). Poult. Sci. 82:1011–1016.

10. Tesseraud, S., N. Maaa, R. Peresson, and A. M. Chagneau. 1996. Relative responses of protein turnover in three different skeletal muscles to dietary skeletal muscles to dietary lysine deficiency in chicks. Br. Poult. Sci. 37:641–650.

11. Stromer, M. H., D. E. Goll, R. B. Young, R. M. Roberson, and F. C. Parrish, Jr. 1974. Ultra structural features of skeletal muscle differentiation and development. J. Anim. Sci. 38:1111–1141.

12. Skinner, J. T., A. L. Waldroup, and P. W. Waldroup. 1992. Effects of dietary amino acid level and duration of finisher period on performance and carcass content of broilers forty-nine days of age. Poult. Sci. 71:1207–1214.

13. Thomas, O. P., A. I. Zuckerman, M. Farran, and C. B. Tamplain. 1986. Updated amino acid requirements of broilers. Pages 79–85 in Proc. Maryland Nutr. Conf., University of Maryland, College Park.

14. Corzo, A., M. T. Kidd, D. J. Burhnham, E. R. Miller, S. L. Branton, and R. Gonzalez-Esquerra. 2005. Dietary amino acid density effects on growth and carcass of broilers differing in strain cross and sex. J. Appl. Poult. Res. 14:1–9.

15. Kidd, M. T., A. Corzo, D. Hoehler, E. R. Miller, and W. A. Dozier, III. 2005. Broiler responsiveness (Ross × 708) to diets varying in amino acid density. Poult. Sci. 84:1389–1396.

16. Aviagen, Inc., Huntsville, AL.

17. Temperature set points consisted of 34°C from placement to 4 d, 32°C from 5 to 9 d, 29°C from 10 to 14 d, 28°C from 15 to 19 d, 27°C from 20 to 24 d, 26°C from 25 to 29 d, 24°C from 30 to 34 d, 22°C from 35 to 39 d, 21°C from 40 to 43 d, and 19°C from 44 to 47 d; 16.5°C from 48 to 51 d; 15.5°C from 52 to 55 d; 14°C from 56 to 59 d.

18. The lighting schedule consisted of continuous lighting with an intensity of 20 lx from placement to 7 d, 19L:5D and an intensity of 20 lx from 8 to 14 d, 20L:4D with an intensity of 5 lx from 15 to 22 d, and continuous lighting with an intensity of 3 lx from 23 to 59 d.

19. National Research Council. 1994. Nutrient Requirements of Poultry. 9th rev. ed. Natl. Acad. Press, Washington, DC.

20. Total feed cost/bird (sum of the starter, grower, WDI, and WD2 periods) for the 6 dietary treatments were: HHLL = $1.149; HHML = $1.153; HHMM = $1.171; HHHH = $1.180; HHHM = $1.187; HHHL = $1.161.

21. SAS Institute. 2004. SAS User's Guide. Statistics. Version 9.1 Edition. SAS Institute, Inc., Cary, NC.

22. Actual temperatures (°C) were 28.9 ± 2.09, 1 to 17 d; 24.03 ± 1.45, 18 to 35 d; 19.65 ± 1.55, 36 to 48 d; 16.63 ± 2.44, 49 to 59 d.